Vendor Selection in Manufacturing Industry using AHP and ANN

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***Abstract*—**Suppliers are one of the most essential components of the value chain, the supplier selection and evaluation process are critically important management task. Supplier selection which is the first step of the activities in the product realization process starting from purchasing of the materials till the end of the products is evaluated as the critical factor for the companies in today's competitive condition. Supplier selection was considered as a Multi Criteria Decision Making Problem. The supplier selection process deploys a tremendous amount of a firm's financial resources. In return, firm's expect significant benefits from contracting with suppliers offering high value. There are many tools to select a supplier in a manufacturing industry. But in this paper we integrate the Analytic Hierarchy Process and Neural Network method to select an optimal vendor in supply chain management. This paper presents a hybrid model using Analytic Hierarchy Process (AHP) and Neural Networks (NNs) theory to review vendor performance. The model consists of two sections: Section 1 applies AHP using pair wise comparison of criteria for all vendors, Section 2 applies the results of AHP into NNs model for vendor selection. The results give up the best vendor.

***Keywords*—**AHP, ANN, MCDM, SCM, Vendor Selection

***Abbreviations*—**Analytic Hierarchy Process (AHP), Artificial Neural Networks (ANN), Analytical Network Process (ANP), Data Envelopment Analysis (DEA), Multi Criteria Decision Making (MCDM), Supply Chain Management (SCM), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS)

I. INTRODUCTION

SCM is one of the most important notion in recent decades. The globalization and the competitiveness have motivated higher attention to SCM process. SCM, which integrates suppliers, manufactures, distributors and customers, is diffused in the firm in order to improve flexibility, cost, quality and delivery performance [Wacker, 1996]. Supplier selection may be single most important phase of the purchasing process [Edward J. Hay, 1990]. The objective of this stage is to find the optimal supplier [Robert L Nydic, 1992]. So, the firm must considered multi criteria in their attempts to distinguish between items offered by potential suppliers [Timmerman, 1986]. It is the important job for decision makers to select proper suppliers in their supplier chain management. They need to use some criteria to evaluate their alternative and find which one is the best for them. Hence the supplier selection problem belongs to the MCDM [Liao, 2008]. In this paper, the vendor selection is based on ten criteria namely commitment to quality, cost, competency, capacity, control, cash, consistency, culture, clean, communication. With the help these criteria an optimal supplier is to be selected by integrating AHP and ANN.

II. LITERATURE SURVEY

Chen et al., (2006) adopted a fuzzy decision making approach to solve the supplier selection problem in the SCM using some criteria such as profitability of supplier, relationship closeness, technological capability, conformance quality and conflict resolution.

Chen et al., (2006) applied a linguistic value to measure the rating and weight of the supplier selection criteria and then used a MCDM model based on fuzzy set theory to analysis SCM.

Liao & Kao (2011) confined the topsis approach is based on the idea that a chosen alternative should be shortest distance from the positive ideal solution and farthest distance from the negative ideal solution. Onut et al., (2009) developed a supplier evaluation approach based on the ANP and TOPSIS method to help a telecommunication company in a vendor selection. Wu & Blackhurst (2009) confined DEA approach to supplier evaluation and selection.

Liao & Kao (2010) integrated the Taguchi Loss Function, AHP and Multi choice goal programming model for supplier selection problem. The modeling of many situations may not be sufficient or accurate as the available data inaccurate, vague, imprecise and uncertain by nature in real life [Sarami et al., 2009].

Marvin et al., (2004) have investigated the importance of the process of supplier selection in production and they have been increasing the quality in the product process through evaluating the supplier. Mikhailov (2002) introduced fuzzy approach for supplier selection in virtual organization. Chen & Lin (2004) used fuzzy decision making frame work to choose the right supplier.

III. MODELS DESCRIPTION

The model consists of two sections; section 1 applies AHP to calculate the weight of each criterion identified for vendor evaluation. Section 2 applies the weight of each criterion for neural network based model to select the best vendor and find alternate vendors on the basis of performance (score) of each vendor.

3.1. AHP Vendor Selection Model

A method of AHP for the vendor selection is described below.
Step 1: Structure of the decision problem can be shown in a hierarchy of goal (best vendor), criteria and alternatives (vendors).
Step 2: Compare the alternatives based on the criteria, adapted from a common scale [Amiri, 2010].
Step 3: Synthesize the comparisons to obtain the priorities of the alternatives with respect to each criteria and the weights of each criteria with respect to the goal. Local priorities are then multiplied by the weight of the respective criteria and the results are summed up to produce the overall priority of each alternative (vendor).

3.2. Neural Network Model

The theory of NNs started in the late-1800s, the term neural network had been used to refer to a network or circuit of biological neurons. The modern usage of the term often refers to ANN, which are composed of artificial neurons or nodes.

NNs offer an original way for trait removal (using hidden layers) and categorization (e.g., multilayer perception). The perceptron is basically a linear classifier for classifying data specified by parameters and an output function. Its parameters are modified with an ad-hoc rule similar to stochastic steepest gradient descent. Since the inner product is a linear operator in the input space, the perceptron can only perfectly classify a set of data for which dissimilar classes are linearly separable in the input space, while it often fails completely for non-separable data

The cognitron (1975) was an early multilayered neural network with a training algorithm. Networks can propagate information in one direction only, or they can rebound back and forth until self activation at a node occurs and the network settles on a final state.

The aptitude for bi-directional flow of inputs between neurons/nodes was formed with the Hopfield's network (1982), and area of these node layers for specific purposes was introduced through the first hybrid network.

The rediscovery of the back propagation algorithm was almost certainly the main reason behind the repopularisation of NNs after the publication of "Learning Internal Representations by Error Propagation". The original network utilized multiple layers of weight-sum units with a sigmoid function or logistic function such as used in logistic regression. There are three major learning paradigms, each parallel to a particular abstract learning task. These are supervised learning, unsupervised learning and reinforcement learning. Usually any given type of network architecture can be employed in any of those tasks.

3.2.1. Supervised Learning

In supervised learning, a set of example pairs (x, y), $x \varepsilon X$, $y \varepsilon Y$ is inputted. The aim is to find a function f in the allowed class of functions that matches the examples. In other words, the aim is intended to how the mapping may be implied by the data and the cost function is related to the mismatch between the referred mapping and the data.

3.2.2. Unsupervised Learning

In unsupervised learning with a given input data x, sigmoid function $[1 / (1 + e^{-\alpha(\Sigma x_i w_i)})]$ is to be minimized which can be any function of x is related to the network's output, y=f(w, x), where w is the matrix of all weight vectors. This method of learning is adopted in this study.

3.2.3. Reinforcement Learning

In reinforcement learning, data x is usually not known and as such cannot be inputted. However it can be generated by an agent's interactions with the environment. At each point in time t, the agent performs an action y_t and the environment generates an observation x_t and an instantaneous cost c_t, according to some (usually unknown) dynamics [Jitendra Kumar & Nirjhar Roy, 2010].

3.3. Steps for Hybrid Model of Vendors Selection

Step 1: Decide the number of vendors
Step 2: Decide the number of criteria for vendors
Step 3: Define the scale for criteria using Saaty's common scale.
Step 4: Apply the data of each vendor.
Step 5: Generate a matrix for comparison of each criteria
Step 6: Create a matrix for the calculation of weights of the criteria

Weight of given criteria = Value of given criteria / Sum of column value

Step 7: Generate the comparison matrix for vendor with respect to given criteria.
Step 8: Create a matrix for the calculation of weights of the vendors with respective to criteria

Weight of given vendor with respective to criteria = Value of given vendor / Sum of column value

Step 9: Create a matrix for hidden layer by using the following formula:

Output value for hidden layer $Yc_i = 1 / (1 + e^{-\alpha(\Sigma X_i Wc_i)})$

X_i = Input value for input layer

W_{Ci} = Weight of criteria

Y_{ci}= Output value for hidden layer α=1

Step 10: Create a matrix for output layer by using following formula:

Value for output layer $Yv_i = 1 / (1 + e^{-\alpha(\Sigma Yc_i Wv_i)})$

Where,

Yc_i = Input value for output layer

$^{Wv}{}_i$ = weights of the vendors with respective to criteria

Yv_i = Total score of vendor

Step 11: Select the vendor of maximum score from the above matrix for the best vendor.

3.4. Criteria to be Used for the Supplier Selection

Carter's ten Cs of supplier evaluation or selection is named after ray Carter who originally devised seven Cs of effective supplier evaluation. This has since been extended to ten and they offer a very clear focus for anyone who is involved in either selecting or evaluating suppliers.

C0. Commitment to Quality – Quality is a key requirement for any business – if the suppliers have the commitment to maintain suitable quality performance

C1. Cost – What is the cost of products from the supplier.

C2. Competency – Supplier have the skills to deliver the materials that company requires

C3. Capacity – The supplier have an adequate "engine room" to produce goods. Capacity can include equipment, human resources and materials. Can supplier flex their capacity in line with requirements.

C4. Control – Is supplier is in control of their policies and procedures. Can it ensure that its performance can be consistent.

C5. Cash – Check whether the supplier have adequate financial standing

C6. Consistency – The supplier guarantee a consistent product time and time again

C7. Culture – The supplier share the same cultural values as the organization. Does it make sense that supplier shares similar values and attitudes to avoid strains in the future relationship.

C8. Clean – Supplier have an appropriate sustainability policy

C9. Communication – What tools will the company utilize to communicate with their supplier.

IV. NUMERICAL ILLUSTRATION

The below data is taken from transformer manufacturing company, which is a leader in production and marketing of power and distribution transformers. The model consists of two sections; section 1 applies AHP to calculate the weight of each criterion identified for vendor evaluation. Section 2 applies the weight of each criterion for neural network based model to select the best vendor and find alternate vendors on the basis of performance (score) of each vendor. The vendor data is shown in table 1.

Table 1 – Vendor Data

	V1	V2	V3	V4	V5	V6	V7
C0	0.5	1.2	0.7	1.5	1.0	0.9	1.1
C1	1.95	1.85	2.35	2.05	1.65	2.20	2.28
C2	VG	AV	O	G	AV	VG	AV
C3	G	VG	G	O	VG	G	AV
C4	VG	O	VG	AV	G	AV	O
C5	G	O	VG	AV	AV	VG	VG
C6	O	AV	VG	VG	AV	G	G
C7	O	G	AV	AV	G	VG	G
C8	VG	AV	G	G	AV	O	AV
C9	G	VG	AV	O	G	VG	VG

O-Outstanding, VG-Very good, G-Good,, AV-Average, P-Poor

Scaling of each criteria is carried out with respect to one selected and considered as the most important criteria using Saaty Rating given in the table 2.These Saaty Rating are taken from [Amiri, 2010].

Table 2 – The Saaty Rating Scale

Intensity of Importance	Definition
1	Equal importance
3	Somewhat more important
5	Much more important
7	Very much more important
9	Absolutely more important.
2, 4, 6, 8	Intermediate values

Table 3 – Performance on Criteria

	C0	C1	C2	C3	C4	C5	C6	C7	C8	C9
C0	1	3	5	7	3	7	5	7	5	3
C1	1/3	1	3	5	7	3	7	5	7	5
C2	1/5	1/3	1	3	5	7	3	7	5	7
C3	1/7	1/5	1/3	1	3	5	7	3	7	5
C4	1/3	1/7	1/5	1/3	1	3	5	7	3	7
C5	1/7	1/3	1/7	1/5	1/3	1	3	5	7	3
C6	1/5	1/7	1/3	1/7	1/5	1/3	1	3	5	7
C7	1/7	1/5	1/7	1/3	1/7	1/5	1/3	1	3	5
C8	1/5	1/7	1/5	1/7	1/3	1/7	1/5	1/3	1	3
C9	1/3	1/5	1/7	1/5	1/7	1/3	1/7	1/5	1/3	1
	3	5.7	10.5	17.3	20.1	27	31.6	38.5	43	46

Scaling of each criteria is carried out with respect to one selected and take into account as the vital criteria quality is somewhat more important than cost–3

Quality is much more important than cost–5

Quality is very much more important than competency–7

Cost is somewhat more important than competency–3

The Performance on criteria is shown in Table 3.

Table 4 – Weight on Criteria

	C0	C1	C2	C3	C4	C5	C6	C7	C8	C9
C0	0.3	0.11	0.06	0.04	0.11	0.04	0.06	0.04	0.06	0.11
C1	0.5	0.17	0.06	0.03	0.02	0.06	0.02	0.03	0.02	0.03
C2	0.47	0.3	0.09	0.03	0.02	0.01	0.03	0.01	0.02	0.01
C3	0.4	0.3	0.17	0.05	0.02	0.01	0.01	0.02	0.01	0.01
C4	0.15	0.35	0.24	0.15	0.05	0.02	0.01	0.01	0.02	0.01
C5	0.25	0.11	0.25	0.18	0.11	0.03	0.01	0.01	0.01	0.01
C6	0.16	0.22	0.09	0.22	0.06	0.09	0.03	0.01	0.01	0.01
C7	0.18	0.12	0.18	0.17	0.18	0.12	0.07	0.02	0.01	0.01
C8	0.11	0.16	0.11	0.16	0.06	0.16	0.11	0.06	0.02	0.01
C9	0.06	0.11	0.15	0.11	0.15	0.06	0.15	0.11	0.06	0.02
AV	0.22	0.19	0.14	0.10	0.08	0.06	0.05	0.03	0.02	0.02

Weight of given criteria = Value of given criteria / Sum of column value. It is shown in Table 4.

Table 5 – Relative Matrix of Vendors with respect to Quality

	V1	V2	V3	V4	V5	V6	V7
V1	1	4	2	5	4	3	4
V2	¼	1	1/3	3	½	1/3	½
V3	1/2	3	1	4	3	2	3
V4	1/5	1/3	¼	1	1/3	¼	1/3
V5	1/4	2	1/3	3	1	½	2
V6	1/3	3	½	4	2	1	2
V7	1/4	2	1/3	3	½	½	1
	2.8	15.3	4.75	23	11.3	7.6	12.8

In this industry for quality maximum rejection parts is 2% and total scale is divided from.5% to 2% (i.e. for difference of 0%=1, 0.1%-0.3%=2, 0.4%-0.6%=3, 0.7%-0.9%=4, 1.0%-1.3%=5, 1.4%-1.5%=6, 1.6%-1.7%=7, 1.8%-1.9%=8, 2%=9).

For cost the total difference of cost is 1.00 Lac/T (i.e. 2.85-1.85=1.00) and difference of each component cost has been taken and scale is used for these differences between 1-9 (i.e. for difference of 0=1, up to.125=2, .126-.250=3, .251-.375=4, .376-.500=5, .501-.625=6, .626-.750=7, .751-.875=8, .876-1.00=9). Relative matrix of vendors with respect to quality is shown in table 5.

Table 6 – Weight on Quality

	V1	V2	V3	V4	V5	V6	V7
V1	0.35	0.08	0.17	0.07	0.09	0.12	0.08
V2	0.26	0.06	0.19	0.02	0.13	0.19	0.13
V3	0.42	0.07	0.2	0.05	0.07	0.1	0.07
V4	0.21	0.13	0.17	0.04	0.13	0.17	0.13
V5	0.35	0.04	0.26	0.03	0.08	0.18	0.04
V6	0.39	0.04	026	0.03	0.06	0.13	0.06
V7	0.31	0.04	0.23	0.02	0.15	0.15	0.08
AV	0.32	0.06	0.21	0.03	0.10	0.14	0.08

Weight of given criteria = Value of given criteria / Sum of column value. It is shown in Table 6.

Table 7 – Relative Matrix of Vendors with respect to Consistency

	V1	V2	V3	V4	V5	V6	V7
V1	0	½	0	5	2	5	½
V2	2	0	2	7	5	7	0
V3	0	½	0	5	2	5	½
V4	1/5	1/7	1/5	0	½	0	1/7
V5	1/2	1/5	½	2	0	2	1/5
V6	1/5	1/7	1/5	0	½	0	1/7
V7	2	0	2	7	5	7	0
	4.9	1.48	4.9	26	15	26	1.48

For un measurable criteria scale is divided between P to O (Poor to Outstanding i.e. P=2, A=3, G=5, VG=7, O=9) by 1 to 9 (i.e. for difference of 1-2=2, 3=3, 4-5=5, 6-7=7, 8-9=9). Relative matrix of vendors with respect to consistency is shown in table 7.

Table 8 – Weight on Consistency

	V1	V2	V3	V4	V5	V6	V7
V1	0	0.4	0	0.04	0.1	0.04	0.4
V2	0.33	0	0.33	0.01	0.14	0.01	0
V3	0	0.4	0	0.04	0.1	0.04	0.4
V4	0.2	0.26	0.2	0	0.07	0	0.26
V5	0.13	0.33	0.13	0.03	0	0.03	0.33
V6	0.2	0.26	0.2	0	0.07	0	0.26
V7	0.33	0	0.33	0.01	0.14	0.01	0
AV	0.17	0.23	0.2	0.02	0.08	0.01	0.23

Weight of given criteria = Value of given criteria / Sum of column value. It is shown in Table 8.

Table 9 – Weight Matrix of Vendors

	V1	V2	V3	V4	V5	V6	V7
C0	0.32	0.06	0.21	0.03	0.1	0.14	0.08
C1	0.12	0.20	0.04	0.09	0.33	0.05	0.03
C2	0.2	0.03	0.4	0.01	0.2	0.2	0.04
C3	0.06	0.2	0.06	0.3	0.2	0.12	0.06
C4	0.17	0.23	0.2	0.02	0.08	0.01	0.23
C5	0.12	0.4	0.12	0.04	0.04	0.12	0.12
C6	0.4	0.04	0.16	0.16	0.4	0.08	0.08
C7	0.4	0.06	0.04	0.04	0.06	0.25	0.06
C8	0.03	0.02	0.08	0.08	0.07	0.4	0.07
C9	0.09	0.11	0.05	0.42	0.09	0.11	0.11

All calculations are acquired by pair wise comparison of vendors with respect to cost, capacity, control, cash, consistency, culture, clean, communication and arranged in table 9.

Table 10 – Output Values for Hidden Layer

Criteria	Weight	Input Value X_i	$\sum X_i W_{ci}$	Output Value for Hidden Layer Y_{ci}
C0	0.228	0.143	0.428	0.605
C1	0.195	0.143	0.395	0.597
C2	0.14	0.143	0.340	0.584
C3	0.10	0.143	0.300	0.574
C4	0.088	0.143	0.288	0.571
C5	0.06	0.143	0.26	0.564
C6	0.05	0.143	0.25	0.562
C7	0.031	0.143	0.231	0.557
C8	0.022	0.143	0.222	0.555
C9	0.021	0.143	0.221	0.555

Output value for hidden layer is calculated in table 10 which is the input values for output layer.

Let input value for all bias neuron = 1

Let weight for all bias neuron = 0.2

X_i = Input value for input layer = 1/7 =.143

Output value for hidden layer $Yc_i = 1 / (1 + e^{-\alpha(\Sigma X_i Wc_i)})$, α=1.

Table 11 – Matrix for Output Layer

	V1	V2	V3	V4	V5	V6	V7
Y_{c0} 0.605	0.32	0.06	0.21	0.03	0.1	0.14	0.08
Y_{c1} 0.597	0.12	0.20	0.04	0.09	0.33	0.05	0.03
Y_{c2} 0.584	0.2	0.03	0.4	0.01	0.2	0.2	0.04
Y_{c3} 0.574	0.06	0.2	0.06	0.3	0.2	0.12	0.06
Y_{c4} 0.571	0.17	0.23	0.2	0.02	0.08	0.01	0.23
Y_{c5} 0.564	0.12	0.04	0.12	0.04	0.04	0.12	0.12
Y_{c6} 0.562	0.4	0.04	0.16	0.01	0.04	0.08	0.08
Y_{c7} 0.557	0.4	0.06	0.04	0.04	0.06	0.25	0.06
Y_{c8} 0.555	0.3	0.02	0.08	0.08	0.07	0.4	0.07
Y_{c9} 0.555	0.09	0.11	0.05	0.42	0.09	0.11	0.11
$\Sigma Yc_i Wv_i$	1.54	1.00	0.97	0.87	0.90	1.04	0.70
Yv_i	0.80	0.73	0.72	0.70	0.71	0.73	0.66

In table 11 total score for all vendors are calculated and see that vendor 1 is the best vendor because it has maximum score (.809) in comparison to all other vendors.

Value for output layer $Yv_i = 1 / (1 + e^{-\alpha(\Sigma Yc_i Wv_i)})$

Where,

Yc_i = Input value for output layer

$^{Wv}{}_i$ = Weights of the vendors with respective to criteria

Yv_i = Total score of vendor, α=1

In this work data of seven vendors with ten important criteria are taken. Here the advantages of AHP and NNs theory are explained. The position of AHP is to analyze weight of each criteria and vendor for neural network. Input value for all neurons is same and it depends up on number of vendors. Input value and weight (assumed) for all bias neurons are same.

V. Conclusion

This paper has developed a hybrid vendor selection model using AHP and NNs. The model consists of two sections: Section 1 applies AHP using pair wise comparison of criteria for all vendors, Section 2 applies the results of AHP into NNs model for vendor selection. Finally a numerical example has been proposed and found that in table 11 total score for all vendors are calculated and see that vendor 1 is the optimal vendor. By validating these hybrid method vendor 1 is the optimal supplier.

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